

What is claimed is:

1. An illumination optical system for use in a projection-type display apparatus that directs light from a light source through the illumination optical system to a display panel so that an image displayed on the display panel illuminated by the light directed thereto is projected through a projection optical system onto a screen, comprising:

a light intensity uniformizing device of which an entrance surface is located at a first conjugate position that is substantially conjugate with the light source and of which an exit surface has a shape geometrically similar to a panel surface of the display panel; and

a reflection optical system for forming an image of the exit surface of the light intensity uniformizing device on the panel surface of the display panel,

wherein, in the reflection optical system, every surface having an optical power is a reflective surface.

2. An illumination optical system as claimed in claim 1, further comprising:

a condenser optical system for condensing the light from the light source onto the entrance surface of the light intensity uniformizing device; and

a color filter, disposed near the entrance surface or exit surface of the light intensity uniformizing device, for changing colors of light exiting from the light intensity uniformizing device on a time-division basis to achieve color display.

3. An illumination optical system as claimed in claim 1,

wherein the reflection optical system comprises:

a first concave reflective surface for forming between the display panel and the light intensity uniformizing device a second conjugate position that is conjugate with the first

conjugate position of the light source; and

a second concave reflective surface for making the second conjugate position substantially conjugate with an entrance pupil of the projection optical system.

4. An illumination optical system as claimed in claim 3,

wherein at least one of the first and second concave reflective surfaces is a free-form surface that is shaped asymmetrically in each of directions respectively parallel to vertical and horizontal directions of the panel surface of the display panel.

5. An illumination optical system as claimed in claim 4,

wherein the concave reflective surface having the free-form surface fulfills the following condition with respect to a radius of curvature thereof at a point at which a ray traveling from a center of the exit surface of the light intensity uniformizing device through a center of the display panel to a center of the entrance pupil of the projection optical system strikes the concave reflective surface having the free-form surface,

$$|CR_y| < |CR_z|$$

where

CR_z represents a radius of curvature as measured in a plane including both a ray incident on the concave reflective surface having the free-form surface and a ray reflected therefrom; and

CR_y represents a radius of curvature as measured in a plane that is perpendicular to the plane including both a ray incident on the concave reflective surface having

the free-form surface and a ray reflected therefrom and that includes a normal vector to that concave reflective surface.

6. An illumination optical system as claimed in claim 3,

wherein the reflective optical system further comprises:

a flat reflective surface for reflecting light from the first concave reflective surface toward the second concave reflective surface.

7. An illumination optical system as claimed in claim 6,

wherein the first and second concave reflective surfaces and the flat reflective surface are so arranged that a direction of an optical axis of the light intensity uniformizing device is substantially coincident with a direction normal to the panel surface of the display panel.

8. An illumination optical system as claimed in claim 3,

wherein the reflective optical system further comprises, as a surface having an optical power:

a convex reflective surface, disposed near the second conjugate position of the light source, for reflecting light from the first concave reflective surface toward the second concave reflective surface.

9. An illumination optical system as claimed in claim 8,

wherein the first and second concave reflective surfaces and the convex reflective surface are so arranged that a direction of an optical axis of the light intensity uniformizing device is substantially coincident with a direction normal to the panel surface of the display

panel.

10. An illumination optical system as claimed in claim 3,
wherein the first and second concave reflective surfaces are integrated together into a single component.

11. A projection-type display apparatus comprising:
a light source for emitting light;
a display panel for displaying an image;
a condenser optical system for condensing light from the light source at a first conjugate position;
a light intensity uniformizing device of which an entrance surface is located at the first conjugate position and of which an exit surface has a shape geometrically similar to a panel surface of the display panel;
a reflection optical system for forming an image of the exit surface of the light intensity uniformizing device on the panel surface of the display panel; and
a projection optical system for projecting the image displayed by the display panel onto a predetermined surface,
wherein, in the reflection optical system, every surface having an optical power is a reflective surface.

12. A projection-type display apparatus as claimed in claim 11, further comprising:
a color filter, disposed near the entrance surface or exit surface of the light intensity

uniformizing device, for changing colors of light exiting from the light intensity uniformizing device on a time-division basis to achieve color display.

13. A projection-type display apparatus as claimed in claim 11,
wherein the reflection optical system comprises:

a first concave reflective surface for forming between the display panel and the light intensity uniformizing device a second conjugate position that is conjugate with the first conjugate position; and

a second concave reflective surface for making the second conjugate position substantially conjugate with an entrance pupil of the projection optical system.

14. A projection-type display apparatus as claimed in claim 13,

wherein at least one of the first and second concave reflective surfaces is a free-form surface that is shaped asymmetrically in each of directions respectively parallel to vertical and horizontal directions of the panel surface of the display panel.

15. A projection-type display apparatus as claimed in claim 14,

wherein the concave reflective surface having the free-form surface fulfills the following condition with respect to a radius of curvature thereof at a point at which a ray traveling from a center of the exit surface of the light intensity uniformizing device through a center of the display panel to a center of the entrance pupil of the projection optical system strikes the concave reflective surface having the free-form surface,

$$|CR_y| < |CR_z|$$

where

CR_z represents a radius of curvature as measured in a plane including both a ray incident on the concave reflective surface having the free-form surface and a ray reflected therefrom; and

CR_y represents a radius of curvature as measured in a plane that is perpendicular to the plane including both a ray incident on the concave reflective surface having the free-form surface and a ray reflected therefrom and that includes a normal vector to that concave reflective surface.

16. A projection-type display apparatus as claimed in claim 13,

wherein the reflective optical system further comprises:

a flat reflective surface for reflecting light from the first concave reflective surface toward the second concave reflective surface.

17. A projection-type display apparatus as claimed in claim 16,

wherein the first and second concave reflective surfaces and the flat reflective surface are so arranged that a direction of an optical axis of the light intensity uniformizing device is substantially coincident with a direction normal to the panel surface of the display panel.

18. A projection-type display apparatus as claimed in claim 13,

wherein the reflective optical system further comprises, as a surface having an optical power:

a convex reflective surface, disposed near the second conjugate position of the

light source, for reflecting light from the first concave reflective surface toward the second concave reflective surface.

19. A projection-type display apparatus as claimed in claim 18,
wherein the first and second concave reflective surfaces and the convex reflective surface are so arranged that a direction of an optical axis of the light intensity uniformizing device is substantially coincident with a direction normal to the panel surface of the display panel.

20. A projection-type display apparatus as claimed in claim 13,
wherein the first and second concave reflective surfaces are integrated together into a single component.

21. A projection-type display apparatus as claimed in claim 11,
wherein, in the projection optical system, every surface having an optical power is a reflective surface.

22. A projection-type display apparatus as claimed in claim 11,
wherein the light intensity uniformizing device is a rod integrator.

23. A rear projection apparatus comprising:
a light source for emitting light;
a display panel for displaying an image;
a condenser optical system for condensing light from the light source at a first

conjugate position;

a light intensity uniformizing device of which an entrance surface is located at the first conjugate position and of which an exit surface has a shape geometrically similar to a panel surface of the display panel;

a color filter, disposed near the entrance surface or exit surface of the light intensity uniformizing device, for changing colors of light exiting from the light intensity uniformizing device on a time-division basis to achieve color display;

a reflection optical system for forming an image of the exit surface of the light intensity uniformizing device on the panel surface of the display panel, wherein every surface having an optical power is a reflective surface;

a projection optical system for projecting the image displayed by the display panel onto a predetermined surface; and

a transmission-type screen onto which the projection optical system projects the image.